

## Cranial Variation in the Iberian Peninsula and the Balearic Islands: Inferences About the History of the Population

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**ABSTRACT** A multivariate analysis of four prehistoric and nine historic populations from the Iberian Peninsula and Balearic Islands with large sample sizes ( $n > 30$  individuals for the neurocranium and  $n > 15$  for the facial skeleton) is presented, considering 874 male and 557 female skulls and using 20 craniometric measurements. Cluster analyses have been undertaken using the squared Euclidean distance as a measure of proximity and the average linkage between groups (UPGMA), and neighbor-joining algorithms as a branching method, and a bootstrap analysis was used to assess the robustness of the clustering topology. The study was complemented with a principal coordinate analysis and with the application of the Mantel test to measure the degree of correspondence between the information furnished by the female and the male samples. The analyses show that the main source of morphometric variability in the Iberian Peninsula is the Basque population. The second source of variation is provided by two populations (Muslims and Jews), different from the rest from an archaeological and cultural point of view, and can probably be attributed to influences from sub-Saharan Africa. The massive deportations of the Jews in 1492 and of the Moors between the 15th and 17th centuries may have erased this source of variability from the present population of the Iberian Peninsula. The remaining studied populations, including samples from Castile, Cantabria, Andalusia, Catalonia and Balearic Islands, are grouped together, showing a notable morphological homogeneity, despite their temporal and geographic heterogeneity. These results are in general agreement with those obtained in synthetic maps, by analyzing multiple genetic markers. In such studies, the Basque population is described as the main source of genetic variability, not only in the Iberian Peninsula, but also in Western Europe. © 1996 Wiley-Liss, Inc.

Skeletal measurements are the product of a continuous interaction between the genotype and the environment. They constitute a combination of unknown proportions of one environmental and one hereditary component (Cavalli-Sforza and Bodmer, 1971; Guglielmino-Matessi et al., 1979), sometimes affected by natural selection (Beals, 1972). Studies with twins have shown that these metrical characters seem to have a heritability coefficient ( $H^2$ ) of around 0.50–0.70

(Clark, 1956; Nakata et al., 1974). Despite this relatively low heritability, the value of the skeletal measurements in reconstructing the population structures in the past continues to seem considerable (Howells, 1984).

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Traditionally, these measurements have been used to define racial types and subtypes, some of which (e.g. "gracile and robust Mediterranean," "alpine," "dinaric" or "western-pyreneic") (Coon, 1939) have been assumed to be present in different proportions in prehistoric and historic populations from the Iberian Peninsula. The proponents of the racial classifications assume that each race can be characterized by type specimens, and that those types have remained constant over long periods of time. On numerous occasions, this rigid typological approach has limited the study of skull samples to a univariate or bivariate focus, thus restricting the view of the human variation as a dynamic process. In recent decades, there has appeared a growing body of craniometric data of different human samples from the Iberian Peninsula, although it has not been supported by an advance in the statistical treatment of the data.

Recently, genetics has acquired a relevant role in the reconstruction of the history of human populations from the Iberian Peninsula. Large amounts of data from genetic markers (mainly from blood groups) have been analyzed, by the generation of synthetic genetic maps, following the method of Menozzi et al. (1978). In these studies (Bertranpetit and Cavalli-Sforza, 1991; Calafell and Bertranpetit, 1994a, 1994b), the major genetic difference in the Iberian Peninsula is between the Basque and non-Basque peoples. This genetic divergence has been interpreted as meaning that the Basques are descendants of pre-neolithic populations that could have survived in a considerable degree of isolation at the western end of the Pyrenees (Cavalli-Sforza, 1988; Calafell and Bertranpetit, 1994b). The fact that Euskera is the only present European language not related to any other extant language (Ruhlen, 1991) also supports the hypothesis of this ancient population persistence.

In contrast, most morphological studies have apparently failed to detect either this major source of variability or the presumed homogeneity of populations of the rest of the Iberian Peninsula, attributing more relevance to some skeletal samples, archaeologically related to possible foreign migrations.

A pioneer study has attempted to provide a global vision of the peninsular peopling (Garralda, 1981), by analyzing 13 archaeological samples, using  $C_H^2$  as a measure of proximity and eight variables from those defined by Martin and Saller (1957). However, results were difficult to interpret, probably due to the inclusion of populations with low sample size, the low number of variables used and the poor statistical properties of the measure of proximity used. Factorial analysis of numerous craniometric variables has been used to define the differential characteristics of the Basque population (de la Rúa, 1985, 1992), although only five samples from the rest of the Iberian Peninsula were compared with this population.

In addition, several studies (Rösing and Schwidetzky, 1977, 1981; Schwidetzky and Rösing, 1984; Sokal et al., 1987) have analyzed a large amount of cranial samples from Europe, finding significant associations between populations and language, geography and time period (Sokal et al., 1987). However, whereas Central and Eastern Europe are strongly represented, the authors recognized that the Iberian Peninsula is underrepresented (Sokal et al., 1987). In the present study, craniometric information from different human populations from the Iberian Peninsula and the Balearic Islands with a large sample size, published over almost 50 years, has been analyzed statistically, in an attempt to draw inferences about the history of these populations. Data examined here make up the largest body of cranial measurements ever assembled for the Iberian Peninsula.

The main purpose of this paper is to investigate if the craniometric distances can be indicative of the population genetic affinities in the Iberian Peninsula, recently studied by Bertranpetit and Cavalli-Sforza (1991). This kind of study can be useful to assess the results obtained by these authors from a completely independent approach, and also to determine the degree of correspondence between the morphological phenotype and the genotype in the west of Europe, which is known to be the most genetically homogeneous continent (Cavalli-Sforza et al., 1994).

TABLE 1. Craniometric variables used to generate the cluster analysis and the principal coordinates analysis

	Variable
Neurocranium	
Maximum cranial length (g-op)	1
Length of the cranial base (ba-na)	5
Maximum breadth (eu-eu)	8
Minimum frontal breadth (ft-ft)	9
Maximum frontal breadth (co-co)	10
Basi-bregmatic height (ba-br)	17
Auricular height (br-po)	20
Frontal arch (na-ba)	26
Parietal arch (br-la)	27
Occipital arch (la-o)	28
Frontal chord (n-br)	29
Parietal chord (br-la)	30
Occipital chord (la-o)	31
Facial skeleton	
Basi-alveolar length (ba-pr)	40
Bizygomatic breadth (zy-zy)	45
Upper facial length (n-pr)	48
Orbital breadth (mf-ek)	51
Orbital height	52
Nasal breadth (al-al)	54
Nasal height (na-ns)	55

Numbers of the variables defined by Martin and Saller (1957).

## MATERIALS AND METHODS

### Selection of the sample

Only populations with a large sample size were selected from the literature (the criteria of  $n > 30$  for the neurocranium and  $n > 15$  for the facial skeleton have been adopted), considering that those with a small number of individuals introduce serious biases in the analysis. Thus, although data of other interesting samples are available [as the Visigoths from Silveirona, Portugal (Cunha and Neto, 1953), or the Basques studied by Marquer (1963)], the sample size or the number of variables are too small and can seriously weaken the analysis. Several variables with a low sample size ( $n < 10$  cases) were omitted (as the interorbital and bi-orbital breadth), although no a priori judgement has been made about the significance of any characteristic for establishing relationships. Twenty cranial variables (13 for the neurocranium and seven for the facial skeleton) of those defined by Martin and Saller (1957) (see also Knussman, 1988) were considered (Table 1). Although archs and chords are considered as noise variables by some authors, they have been included in the study, in order to attempt to represent the maximum number of genes involved in the proportions of the skull.

Other biases, as differences in the sample sizes depending on which measurement is being examined, or differences in the sexing of the skulls, may be inherent in this type of data, as Sokal et al. (1987) pointed out. Female and male samples were considered separately, and sexing results were accepted unchanged from the literature. Several female populations were omitted from the analysis, due to small sample size, as is common in archaeological samples (Brothwell, 1971). Finally, 13 male and 10 female populations were taken into account. The samples and their estimated dating are presented in Table 2. The mean values of the craniometric variables used in the analysis are displayed in Table 3.

The populations studied include different historic and prehistoric periods (medieval being the best represented) making up about 4,000 years of the history of the Iberian Peninsula. In this dating span, numerous invasions and movements of people from Central/North Europe and from North Africa took place, building a complex archaeological problem. The samples available are concentrated in four main areas: Catalonia, Balearic Islands, Granada and the Center-North peninsular region (Fig. 1). It is assumed that the distribution of the samples, and also the lack of additional samples from the Basque country, can represent a bias in the results.

The Basque population (BAS) was excavated from several 19th century necropolises found within the linguistic and cultural Basque area, selecting individuals on the basis of place of birth and the names found in the ecclesiastic registers, in order to ensure their Basque origin (de la Rúa, 1985). The population from Tarragona (TAR) corresponds to a large necropolis from the late Roman times, when Tarraco (Tarragona) was the political center of the Hispania Citerior province. Son Real (MAL1) is a site of the Talayotic culture, in the north coast of Majorca, the largest Balearic Island. Another necropolis (MAL2) was found on a small island (s'Illot des Porros) in the vicinity. These sites seem to correspond to different chronological and cultural moments of the same population (Malgosa, 1992). Palacios de la Sierra (BUR1) and Villanueva de

TABLE 2. *Samples from the Iberian Peninsula considered in the study*

Code	Maximum sample size		Site/region	Period	Dating	Reference
	Males	Females				
BAS	100	70	Basque country	Contemporary	ca. 19th century A.D.	de la Rúa (1985)
TAR	103	62	Tarragona	Roman	ca. A.D. 200–500	Pons (1949)
MAL1	56	—	Son Real (Alcudia, Majorca)	Talayotic	ca. 5th century B.C.	Font (1977)
BUR1	33	—	Palacios de La Sierra (Burgos)	Medieval (Christian)	ca. A.D. 900–1300	du Souich et al. (1990)
MUS	47	47	La Torrecilla (Granada)	Medieval (Muslims)	ca. A.D. 800–1400	du Souich (1979)
VIS	88	88	North Meseta	Visigothic	ca. A.D. 400–700	Varela (1974–75)
CAN	55	40	Santa Maria de Hito (Cantabria)	Medieval (Christian)	ca. A.D. 500–1200	Galera and Garralda (1992)
CAT1	120	80	Central Catalonia	Bronze Age	2000–1000 B.C.	Turbón (1981)
BUR2	26	—	Villanueva de Sopotilla (Burgos)	Medieval (Christian)	ca. A.D. 800–1200	du Souich et al. (1991)
JEW	37	18	Montjuich (Barcelona)	Medieval (Jews)	ca. A.D. 1000–1400	Prevosti and Prevosti (1951)
MAL2	55	54	Illot des Porros (Majorca)	Talayotic	ca. 500–100 B.C.	Malgosa (1992)
CAT2	74	45	Central Catalonia	Medieval (Christian)	ca. A.D. 800–1100	Vives (1987)
GRA	80	53	Upper Andalusia (mainly Granada)	Bronze Age	1800–1200 B.C.	Jiménez (1987)

TABLE 3. Mean values of the craniometric variables of the male and female samples

	1	5	8	9	10	17	20	26	27	28	29	30	31	40	45	48	51	52	54	55
<b>Male sample</b>																				
BAS	188.39	100.02	143.53	97.29	123.21	130.61	112.39	130.27	126.69	121.69	113.73	115.15	98.62	92.27	129.08	73.41	41.67	35.09	22.74	54.28
TAR	186.93	102.47	142.07	97.18	120.38	133.72	114.48	126.61	130.44	120.30	112.01	117.24	98.03	95.56	134.84	71.97	40.81	33.68	24.93	52.94
MAL1	188.56	104.52	140.29	97.31	118.02	137.58	118.57	131.71	130.11	119.31	113.89	116.00	98.69	95.72	133.22	69.20	40.83	32.11	23.50	51.37
BUR1	187.90	100.31	140.02	95.28	119.32	133.63	113.42	131.26	131.64	119.88	114.06	117.92	97.26	92.95	130.36	72.38	40.96	32.84	24.95	53.31
MUS	184.74	101.46	135.69	96.30	116.32	135.31	114.04	128.64	131.24	116.64	111.69	117.61	96.63	97.34	128.47	69.86	41.97	33.38	24.86	51.69
VIS	190.87	102.90	140.20	97.42	118.47	137.00	113.27	130.49	130.92	123.83	114.05	117.61	100.31	97.70	129.51	72.44	41.15	32.87	25.49	52.38
CAN	192.68	101.40	142.12	97.82	122.08	136.68	115.77	130.94	131.82	122.88	114.44	118.32	100.09	94.00	130.69	75.12	40.30	33.91	24.40	53.52
CAT1	188.07	100.97	141.04	95.74	119.48	135.07	114.74	129.54	128.68	121.07	112.89	115.90	100.28	95.57	128.49	68.05	41.42	31.87	23.70	51.24
BUR2	186.68	101.76	140.65	94.63	118.79	137.71	113.89	127.68	130.64	119.95	111.84	117.13	100.03	96.87	129.69	70.09	40.46	32.10	22.39	51.89
JEW	187.88	103.00	139.60	98.87	118.03	132.50	112.06	127.03	134.46	117.38	111.90	120.03	96.76	95.57	131.00	71.06	44.00	35.78	24.17	52.82
MAL2	186.82	101.22	139.59	97.61	119.67	134.96	115.17	129.65	127.26	119.14	113.07	115.00	98.57	98.32	134.00	70.46	39.92	30.95	23.60	51.04
CAT2	189.28	102.47	139.52	96.54	120.05	135.43	113.98	131.16	129.35	122.14	113.62	115.54	100.14	94.26	131.45	69.63	38.10	33.59	23.96	52.40
GRA	186.45	100.29	140.07	95.14	117.91	133.56	112.47	128.74	129.34	120.54	112.44	116.54	100.38	95.69	128.61	70.72	40.89	32.09	24.26	50.04
<b>Female sample</b>																				
BAS	179.75	95.03	138.85	94.97	118.40	125.21	108.93	126.30	120.48	118.18	109.58	109.96	95.86	88.44	121.95	68.55	38.48	33.92	22.57	50.73
TAR	179.72	96.62	137.68	95.41	116.79	128.96	110.68	126.00	126.84	116.74	108.34	113.98	95.83	90.55	125.65	67.59	39.36	33.42	23.99	49.97
MUS	176.26	96.16	132.83	92.88	112.66	128.85	110.35	124.10	123.89	112.73	107.37	111.58	94.14	91.64	119.77	65.16	41.11	32.31	23.49	49.02
VIS	181.51	99.00	135.63	97.42	118.47	132.34	108.04	126.11	127.33	114.93	110.22	113.29	94.97	93.33	124.92	68.00	39.13	32.82	24.03	49.61
CAN	185.11	98.43	138.17	94.43	118.91	131.84	111.94	126.67	127.94	118.14	110.40	114.93	96.92	91.05	124.03	69.36	38.71	33.10	23.13	50.08
CAT1	179.65	94.77	136.35	94.01	116.50	129.54	111.27	124.73	125.44	116.91	108.04	112.47	97.24	91.12	122.28	63.97	40.13	31.23	23.00	48.44
MAL1	179.82	97.00	136.38	95.23	115.20	128.93	109.77	125.28	123.84	116.54	109.13	111.98	95.98	93.59	125.24	64.91	38.32	31.05	22.59	47.86
JEW	177.94	96.83	133.64	94.17	114.56	127.17	109.80	123.76	126.24	113.36	108.41	113.82	95.07	92.11	120.63	66.70	42.18	34.36	23.36	50.27
CAT2	181.44	97.19	136.40	94.00	114.00	131.17	110.32	126.58	126.97	118.04	108.71	119.91	97.07	90.00	120.46	66.76	37.47	32.94	22.93	48.93
GRA	179.71	94.06	137.17	92.72	116.78	129.94	110.80	126.05	125.38	115.79	108.51	112.79	96.21	94.78	121.50	67.50	39.00	30.46	23.04	48.25

Numbers in column heads are the Martin and Saller (1957) variables displayed in Table 1. For abbreviations, see Table 2.

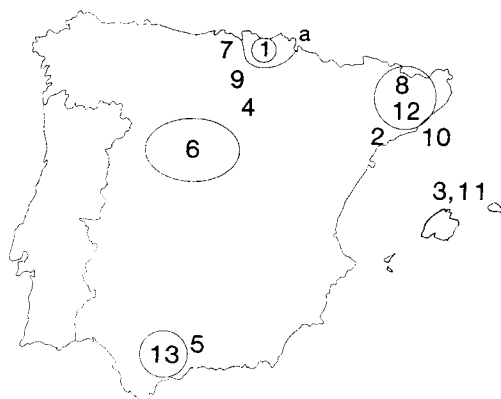


Fig. 1. Geographic location of the samples considered. 1, Basque population (BAS); 2, Romans (TAR); 3, Talayotic (MAL1); 4, Medieval (Christian) (BUR1); 5, Medieval (Muslim) (MUS); 6, Visigothic (VIS); 7, Medieval (Christian) (CAN); 8, Bronze Age (CAT1); 9, Medieval (Christian) (BUR2); 10, Medieval (Jewish) (JEW); 11, Talayotic (MAL2); 12, Medieval (Christian) (CAT2); 13, Bronze Age (GRA); a, present-day limits of the Euskera language.

la Soportilla (BUR2) are two rural medieval necropolises from the period of the Reconquest, and immediately posterior. La Torrecilla (MUS) is a rural necropolis in which the skeletons were oriented facing the east and the corpses were laid on their right side, following the Muslim ritual (du Souich, 1979). The samples corresponding to Visigoths from the Northern Meseta (VIS) were gathered from different necropolises where archaeological evidence of Visigothic origin was found (Varela, 1974–75). This Visigothic sample includes those previously studied by Barras de Aragón (1927) and Schwidetzky (1957). The population of Cantabria (CAN) was excavated from a small medieval necropolis in an isolated valley in the north of the Peninsula. The sample from the Bronze Age from Catalonia (CAT1) groups skeletal material from various inhumations, both from megalithic tombs and sepulchral caves (Turbón, 1981), scattered through the interior landscape. Approximately of the same period is the Bronze Age sample from different burials from the South of Andalusia, mainly from the region of Granada (GRA). The sample of Jews (JEW) was excavated from medieval site in the mountain of Montjuich, then outside the city of Barcelona. The feet of the skeletons were oriented to the

east, and several tombstones with Hebrew inscriptions were found (Prevosti and Prevosti, 1951). The occupation ended with the massive slaughter of the Jewish community in 1391. The sample of medieval Catalonia (CAT2) was gathered from different rural necropolises from the interior and the north of Catalonia, most of them dating from the Repopulation period or immediately posterior (Vives, 1987).

### Multivariate analysis

The methods used in the analysis employ the sample means reported in the original publications, which is the only available information for this data set. Thus, the information about intrapopulation variation is lost. The multivariate treatment has been carried out from a matrix  $13 \times 20$  in size for the male sample and  $10 \times 20$  for the female sample. Male and female samples were analyzed independently, due to sexual dimorphism in the skull. Because the measures of each individual are not available, and because there are not scale changes, the squared Euclidean distance is specially recommended as a measure of proximity for these normally distributed metrical variables (Bisquerra, 1989). Cluster analysis was performed from the distance matrix, using two associating algorithms, the average linkage between groups (UPGMA) (Sneath and Sokal, 1973), and the neighbor-joining method (Saitou and Nei, 1987; Felsenstein, 1989). The robustness of the branches was assessed by applying bootstrap analysis (Efron, 1982; Felsenstein, 1985), performing 500 resamplings of the data set. The bootstrap is a random sampling of the data set, achieved by drawing points from it with replacement. For each resampling, the distance matrix is computed and the corresponding UPGMA and neighbor-joining tree are constructed. Finally, a percentile of each node from the original tree repeated in the bootstrap can be computed. This method indicates whether the clustering between samples is based on numerous or only a few variables. In the latter case, the number of repetitions in the bootstrap would tend to be low. The bootstrap was performed with a microcomputer program designed by F. Calafell (Universitat de Barcelona), and the

graph was drawn with the PHYLIP package (Felsenstein, 1989).

The cophenetic correlation coefficients,  $r_{cs}$  (Sneath and Sokal, 1973), were computed with the NT-SYS statistical package for measuring the degree of correspondence between the obtained phenogram and the original resemblance matrix. Low values of  $r_{cs}$  (less than 0.6) indicate the existence of a large distortion between the original data and the phenogram classification.

Principal coordinates have been extracted from both the male and the female distance matrices. The principal coordinates analysis reveals the latent structure of the data set and the meaning of the differences between populations, since it is possible to determine which variables are correlated with the same principal coordinate. The original papers usually record that the craniometric variables are normally distributed, and thus this statistical approach seems adequate for this sample data.

The Mantel test (Mantel, 1967) was applied to examine the congruence between the distance matrix obtained for the male samples with that obtained for the females, to determine whether the information yielded by each sex is similar. The male groups with no information for the female sex were eliminated from the distance matrix, thus obtaining two diagonal matrices  $10 \times 10$  in size. Following the methodology of Smouse et al. (1986), the Mantel correlation coefficient was computed. Significance of the correlation was obtained through 10,000 permutations at random of rows and columns.

In order to test if the differences observed between populations can be simply attributed to geography, a spatial distance matrix has also been computed, estimating the distances between the sites or centers of regions from which the samples derive. Thus, a Mantel test (10,000 permutations) has also been applied between the Squared Euclidean distance matrix and the geographical matrix (both  $13 \times 13$  in size).

## RESULTS

### Distance matrices

Two distance matrices (for the male and for the female samples) have been computed, using the squared Euclidean distance (Table

4). The standard errors of the distances were estimated from the 500 bootstrap iterations (Table 4). All distance values are larger than twice their standard errors. It can be observed that the Basque sample presents high values of distance with respect to the other populations, even with those geographically close to it, as CAN, BUR1 and BUR2.

### UPGMA clustering analysis

In the UPGMA clustering analysis for the males (Fig. 2), the Basque population constitutes the first factor of morphological variability in the whole Iberian Peninsula. If the phenogram is interpreted in terms of a branching model, then the results suggest an early separation of the Basque population from the rest. However, a tree does not indicate if differences in branches are due to differences in the evolutionary story of the populations or to migrations. The second factor of variation corresponds to two populations that are different from the others for religious and, probably, for ethnic reasons: the Jewish sample of Barcelona and the Muslim sample of Granada. Their morphological differentiation could be attributed in these cases to the contribution of foreign genes and morphologies, and could not indicate an ancient *in situ* differentiation, as is the case of the Basques.

The remaining samples considered, despite their geographical and archaeological heterogeneity, form a single group of clusters, which shows their relative morphological homogeneity. A general morphological continuity from the Neolithic to modern times has already been described by several authors (Garralda, 1986; Garralda and Mesa, 1984, 1986; Turbón, 1989). Neither clear temporal variation in the cranial morphology nor the tendency toward brachycephalization observed in Europe from around A.D. 1000 (Sokal and Uytterschaut, 1987) can be observed, although large samples from early periods (Neolithic, Bronze Age) are scarce, and thus, we lack suitable long-term temporal comparisons.

The UPGMA representation of the female sample (Fig. 3) coincides with that of the male, especially in the main nodes. This concordance can be interpreted as a sign of the reliability of the results.

TABLE 4. Distance matrices and standard errors for the male and the female samples

Male sample													
	BAS	TAR	MAL1	BUR1	MUS	VIS	CAN	CAT1	BUR2	JEW	MAL2	CAT2	GRA
BAS	0	0.33	0.60	0.27	0.70	0.49	0.45	0.35	0.53	0.60	0.43	0.29	0.29
TAR	1.24	0	0.29	0.26	0.53	0.32	0.35	0.41	0.29	0.21	0.14	0.22	0.37
MAL1	2.30	0.97	0	0.31	0.31	0.32	0.38	0.26	0.25	0.47	0.17	0.20	0.41
BUR1	0.94	0.72	1.07	0	0.26	0.27	0.23	0.21	0.23	0.21	0.33	0.12	0.15
MUS	2.66	1.38	1.34	1.00	0	0.58	0.75	0.34	0.27	0.17	0.32	0.36	0.25
VIS	1.68	1.06	0.98	0.82	1.53	0	0.18	0.19	0.22	0.43	0.30	0.15	0.22
CAN	1.28	1.17	1.32	0.85	2.59	0.57	0	0.50	0.38	0.36	0.40	0.31	0.39
CAT1	1.18	0.93	0.76	0.69	1.06	0.70	1.29	0	0.08	0.35	0.29	0.12	0.09
BUR2	1.77	0.75	0.81	0.79	0.78	0.73	1.37	0.33	0	0.34	0.21	0.13	0.18
JEW	2.07	0.88	1.76	0.94	0.90	1.49	1.90	1.55	1.28	0	0.55	0.46	0.30
MAL2	1.67	0.61	0.60	1.03	1.13	1.10	1.68	0.63	0.69	1.76	0	0.18	0.27
CAT2	1.13	0.78	0.63	0.58	1.45	0.55	0.82	0.40	0.63	1.68	0.65	0	0.12
GRA	1.23	0.87	1.22	0.56	0.76	0.79	1.55	0.25	0.36	1.26	0.72	0.63	0

Female sample										
	BAS	TAR	MUS	VIS	CAN	CAT1	MAL2	JEW	CAT2	GRA
BAS	0	0.43	0.44	0.64	0.70	0.32	0.30	0.42	0.97	0.45
TAR	1.06	0	0.43	0.14	0.28	0.16	0.13	0.31	0.40	0.24
MUS	1.98	1.44	0	0.43	0.79	0.23	0.35	0.07	0.66	0.23
VIS	1.94	0.55	1.90	0	0.20	0.22	0.18	0.32	0.46	0.30
CAN	1.89	0.65	2.89	0.70	0	0.38	0.33	0.53	0.32	0.31
CAT1	1.17	0.49	0.84	1.09	1.21	0	0.11	0.14	0.48	0.17
MAL2	1.21	0.49	1.06	0.75	1.30	0.36	0	0.26	0.60	0.17
JEW	1.66	0.85	0.35	1.23	1.96	0.75	0.97	0	0.40	0.20
CAT2	2.27	0.92	1.92	1.39	0.97	1.04	1.33	1.38	0	0.51
GRA	1.36	0.67	1.02	1.00	1.16	0.36	0.48	0.91	1.17	0

Below diagonal, squared Euclidean distances; above diagonal, estimation of the standard errors after 500 iterations of bootstrap.

Neighbor joining clustering analysis

This analysis produces a different representation of the distance matrix, since it is an unrooted tree, whose branches have different lengths. Long branch lengths can be interpreted as an indicator of large morphological differentiation. The male (Fig. 4) and the female trees (Fig. 5) have a similar topology, again displaying the marked divergence of the Basque population. Muslim and Jewish samples would be the most distant populations from the Basque sample, constituting the furthest points of morphological variability in the Iberian Peninsula. The other populations are relatively undifferentiated, closely distributed between these two ends.

Bootstrap

In the UPGMA trees (Figs. 2 and 3), the bootstrap supports the main branches of the cluster reasonably well, especially the separation between Basques and non-Basques (35.0%) and the separation of the Muslim and the Jewish sample in one cluster (48.2%). In 26.6% of the cases, the first split comprises both the Basques and the Cantabrian sample (CAN), forming a Basque-Cantabrian cluster. The grouping of the other

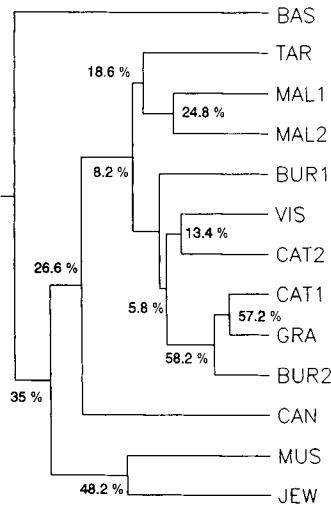


Fig. 2. Average linkage phenogram (UPGMA) based on the squared Euclidean distance for the male samples. Percentages indicate the frequency of each branch among 500 bootstrapped trees. Abbreviations are defined in Table 2.

populations is weak, as expected by the short branches lengths, thus showing that they can be linked in different ways. This is a consequence of their homogeneity. Several



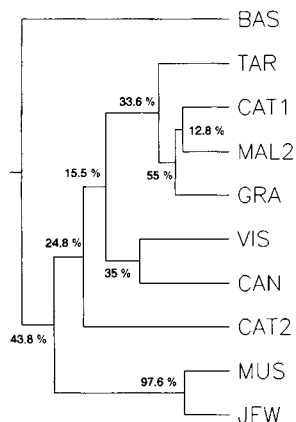


Fig. 3. Average linkage phenogram (UPGMA) based on the squared Euclidean distance for the female samples. Percentages indicate the frequency of each branch among 500 bootstrapped trees. Abbreviations are defined in Table 2.

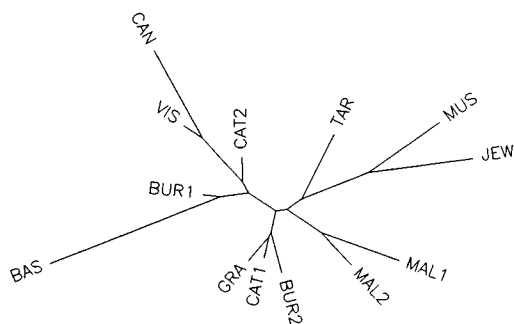


Fig. 4. Neighbor-joining tree based on the squared Euclidean distance, for the male sample. See Table 2 for the abbreviations.

secondary clusters, such as that of the two Talayotic samples (MAL1 and MAL2) (24.8%) or that of the two Bronze Age samples (CAT1 and GRA) (57.2%), are robust. The robustness of the bootstrap in the female tree is larger than the male tree. The Basque sample is the first split in 43.8% of the bootstrapped trees, and the Muslim-Jewish group in 97.6% of the cases. In the neighbor joining trees, the results of the bootstrap are more robust than the UPGMA trees, supporting the main clusters (Basque cluster in 46.2% in the males and 51.6% in the females; the Muslim-Jewish cluster in 82.0% in the males and 95.0% in the females).

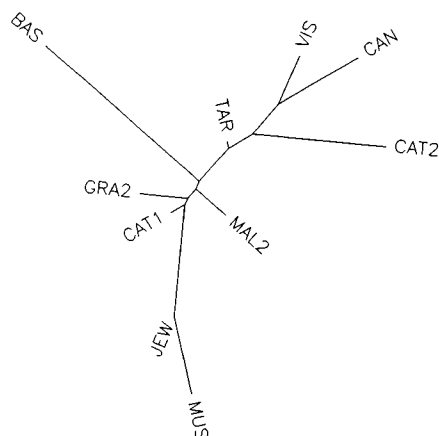


Fig. 5. Neighbor-joining tree based on the squared Euclidean distance, for the female samples. See Table 2 for the abbreviations.

### Cophenetic correlation coefficients

The cophenetic correlation coefficients obtained are reasonably high ( $r_{cs} = 0.7164$  for the male sample and  $r_{cs} = 0.6812$  for the female sample). These coefficients indicate that our data can be satisfactorily arranged in a hierarchic classification, and thus, the populations studied can be grouped on the basis of craniometric resemblances.

### Principal coordinates analysis

A principal coordinates analysis (Harman, 1980) was performed with the male and female data set. In the male analysis, the first and second principal coordinates, which account for 72.11% of the original variation (48.04% and 24.07% respectively), were considered for graphic representation (Fig. 6). The first principal coordinate is mainly correlated with the lengths and breadths of the neurocranium [maximum cranial length, maximum cranial breadth, maximum frontal breadth, frontal arch, occipital arch, frontal chord (all in negative sense) and basi-alveolar length (in positive sense)] and with the heights of the face (upper facial length and nasal height, in negative sense). The second principal coordinate is mainly correlated with the cranial heights (basi-bregmatic height and auricular height) and with the orbital shape (orbital breadth, orbital height, in negative sense). In addition, the

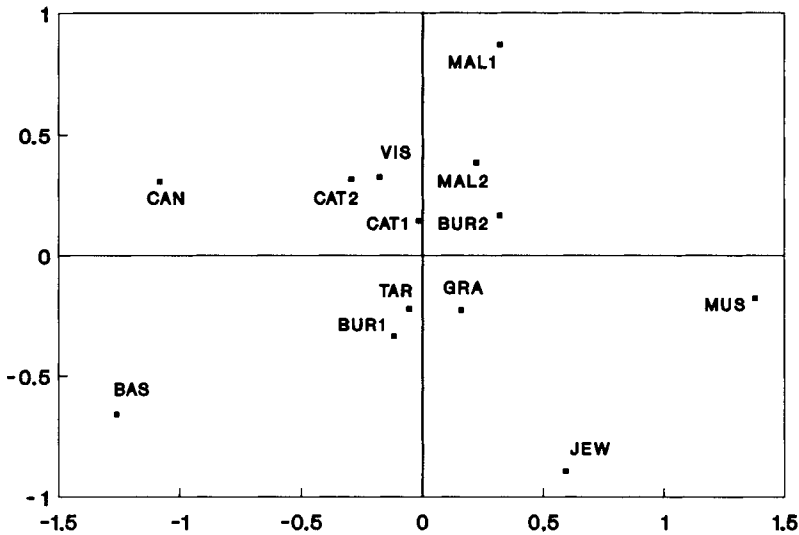


Fig. 6. Plot of the 13 male samples along the first (horizontal) and second (vertical) principal coordinates obtained from the distance matrix. Axes I and II comprise 72.11% of the total variance. See Table 2 for the abbreviations.

third coordinate explains 16.66% of the variance and is mainly correlated with the length of the cranial base and the basi-bregmatic height; it basically contributes to separate the Basques from the Cantabrian population.

The first principal coordinate places the Basques closest to the Cantabrian population, and separates both samples from the others, basically due to their large maximum cranial length, maximum cranial breadth, maximum frontal breadth, upper facial length and nasal height. The fact that the Basque sample has a notably low basi-bregmatic height helps to differentiate it from the peninsular group by the second coordinate and from the Cantabrian population by the third coordinate. Most of the populations conform to a relatively homogeneous whole around the intersection of the first and second axes, with the exception of the Muslims and the Jews. These two populations seem to be notably different from the others, and also from each other. Jews are mainly affected by the axis II, while the Muslims are affected by the axis I. This may be related with the special form of the orbits in the former and with the form of the nose (low and wide), the large basi-alveolar length (re-

lated to prognathism) and the form of the neurocranium (small and narrow) in the latter. However, they are not separated by the third coordinate. The remaining populations show a medium values of most of the variables, which account for a general meso-dolichomorph morphology.

The principal coordinates of the female samples show a similar arrangement of the populations (Fig. 7). The first two principal coordinates account for 76.35% of the total variation (55.71% the first and 20.64% the second). The first coordinate emphasized the separation of the Basques and the Cantabrian sample (in negative sense), and the Jews and Muslims (in positive sense), while the third separates the Basques from the remaining populations.

#### Mantel test: Correlation between the male and the female distance matrices

The Normalized Mantel statistic obtained, which is equivalent to a correlation coefficient ( $r$ ), was 0.6721, and the permutational probability to observe a higher or equal correlation, based on 10,000 permutations, was  $P = 0.001$ . The value obtained indicate a highly significant correlation between the distance matrices obtained for the male and

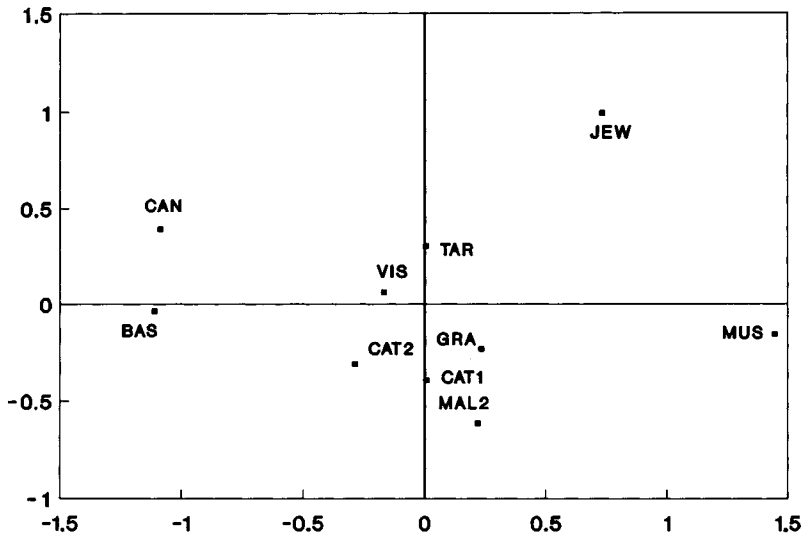


Fig. 7. Plot of the 10 female samples along the first (horizontal) and second (vertical) principal coordinates. Axes I and II comprise 76.35% of the total variance. See Table 2 for the abbreviations.

the female samples. This degree of concordance between sexes reinforces the validity of the information found in the previous analysis.

#### **Mantel test: Absence of correlation between geography and morphology**

The Mantel correlation coefficient between the Euclidean and the spatial distance matrices was 0.1942, with a  $P = 0.073$ . This means that the differences observed in the cranial morphology in the Iberian Peninsula cannot be explained by geography alone.

#### **DISCUSSION**

The Basque population has attracted the attention of physical anthropologists since the second half of the 19th century (Broca, 1862; Collignon, 1895; Aranzadi, 1894; see de la Rúa, 1990, for a review). The Basque skull presents several special morphological traits, extensively described by de la Rúa (1985, 1992). The Basques have a large maximum cranial length and the highest maximum breadth and maximum frontal breadth of our sample. In contrast, they present the lowest basi-bregmatic height of all the peninsular samples, a character also observed by Morant (1929) and Garralda and Mesa (1986) in other samples of Basque origin.

This trait was already described by Aranzadi (1922) as "introversion of the basion," and was explained by Fusté (1966) by a sloped position of the foramen magnum, resulting in a more elevated situation of the anterior point (basion) with respect to the posterior (opisthion). Moreover the Basques have a non-projecting (short basi-alveolar length) but very high face (high upper facial height), with an extremely long and narrow nose (high nasal height and low nasal breadth). This trait has also been described in present-day Basque populations (Rebato, 1987; Rebato and Calderón, 1988).

Santa María de Hito (CAN), Palacios de la Sierra (BUR1) and Villanueva de la Soporilla (BUR2) are grouped in the cluster analysis with the remaining peninsular populations, although they are relatively close to the limits of the ancient Basque-speaking area, which has been receding in the last centuries (Allières, 1986). Probably, the distinctive features of the Basques have been diluted in the Ebro Valley area from historic times. This was a zone of contact with people from the west through the North Meseta, with people from Aquitania (from the North), and with people coming from the south and the southeast of the peninsula (de la Rúa, 1990). The observed morphometric

boundary between neighboring populations, at least from medieval times, could also suggest a sharp genetic boundary between Basque and non-Basque populations to the south. This boundary was already observed by Barbujani and Sokal (1990). In fact, the maintenance of the genetic differentiation of the Basques should be interpreted in terms of isolation, perhaps since Upper Palaeolithic times (Cavalli-Sforza, 1988). Endogamy associated to the language probably contributed to this isolation from the neighboring people (Cavalli-Sforza, 1988, Bertantpetit and Cavalli-Sforza, 1991).

The presence of outliers in a tree can be interpreted in two different ways; assuming constant evolutionary rates, the outlier group must be older than the others, as can be interpreted in the case of the Basques. However, if the outlier group had a small population size because of geographic or social isolation, then these factors increment genetic drift, and can augment the evolutionary rate. This was probably the case of the Jewish groups established in the Iberian Peninsula. On the other hand, if the amount of morphological change found in Basques is assumed to be a linear function of the time, then this population must be older than the others.

Muslims from Granada and Jews from Barcelona constitute the second source of morphological variability in the Peninsula. The original studies of these samples (Prevosti and Prevosti, 1951; du Souich, 1979) described the presence of morphological traits non-characteristic from the Mediterranean area, which were attributed to "Negroid" influences. According to the authors, this influence would become apparent in several individuals (7.15% of the Jews and 16.84% of the Muslims studied) by a large total prognathism, large interorbital breadth and a tendency toward a low and wide nasal aperture. These traits influence different variables from our data set, mainly the length of the cranial base/basi-alveolar length, the nasal breadth/height and the orbital breadth/height, as the principal coordinates analysis pointed out.

The mitochondrial marker HpaI (morph 3) at np 3592 (Denaro et al., 1981), original from sub-Saharan Africa, where it displays

frequencies between 60–90% (Denaro et al., 1981; Soodyall and Jenkins, 1992), is also present in Jewish and Arabian present-day populations in proportions that fluctuate from 0% to 18% (Bonné-Tamir et al., 1986; Ritte et al., 1993). It is interesting to note that some Jewish communities probably entered the Iberian peninsula from North Africa, during the Muslim invasion. This possible African influence, although residual, could have compelled the separation of the Muslim and Jewish populations from the peninsular non-Basque populations. This hypothesis could be corroborated in the future by ancient mtDNA analysis in skeletal remains from these two sites.

During the Muslim occupation, an important portion of the autochthonous people converted to Islam (they were the so-called "muladies"). Necropolises from areas mainly inhabited by these converts probably would not show a morphological differentiation with respect to the Christian peninsular substrate of the same period, represented in our study by populations like CAT2, CAN, BUR1 and BUR2. The special morphological characteristics of La Torrecilla (MUS) can be related to the presence of immigrants from North Africa at this specific site, perhaps Bereberes (du Souich, 1979), as indicated by the existence of some peculiarities in the construction of the tombs.

The Jews must have been a numerically small and a socially isolated and highly endogamous group (Caro-Baroja, 1978). A community of only 500 individuals has been proposed to have lived in Barcelona, at the beginning of the 11th century (Feliu, 1978). They do not represent the general characteristics of the medieval Catalan population, since their roots lie in the ancestral Jewish population which apparently originated in Israel 4,000–5,000 years ago. In any case, the deportation of the Jews in 1492, of the Muslims from the kingdom of Granada between 1502 and 1525 and of the Moors (the Muslims who remained in Spain after the end of the Reconquest) between 1609 and 1614 could have almost eliminated this source of variation from the Iberian Peninsula. The demographic contingent displaced in both cases is not negligible. According to contemporary chroniclers, around 100,000

Jews were deported in 1492 (Suárez, 1991). With regard to the Moors, the deportation at the beginning of the 17th century has been estimated to be 272,140 people (Nadal, 1991), representing 4.05% of the total peninsular population, estimated at 6,719,000 (Nadal, 1991), and they depopulated vast regions of the south and southeast. This could explain why the synthetic maps based on genetic data from the present-day populations have not detected this possible source of variation, which in the case of Muslims must have constituted an important population component, at least in the southeast of the peninsula.

The remaining populations we have examined are grouped together, forming a rather homogeneous block, with several particularities. In the male UPGMA analysis and the principal coordinates analysis, a population from the northern Atlantic mountains (CAN) seems to be detached from the rest. This may be the consequence of the ancient cultural development of the Basque-Cantabrian area during the Upper Paleolithic and the Mesolithic (Butzer, 1986; Straus, 1991; Zvelebil and Rowley-Conwy, 1986), and can reflect to some extent an ancestral relationship with the Basques. The isolation of the Cantabrian area, even during the Roman, the Visigoth and the Arabian conquests (Caro-Baroja, 1973), could have maintained morphological differences arising in pre-neolithic times. The female sample from Cantabria is grouped with the Visigoth population of the North Meseta, thus showing fewer morphological particularities, although it lies closest to the Basques in the principal coordinates analysis. This discrepancy can be the result of sampling bias in this isolated rural community. However, the Mantel test result strengthens the fact that the male and female grouping are similar in their main nodes, and the Cantabria sample constitutes the only important discrepancy.

The two populations from the Balearic Islands (MAL1 and MAL2) are grouped together, as expected, forming an insular-east coast cluster with the Roman sample from Tarragona. Neither the presumed oriental influences of the Balearic Talayotic period (Harrison, 1988) nor the insular isolation seem to have contributed important morpho-

logical differences to the peninsular substrate. In fact, as the result of the Mantel test in spatial distances points out, geography is not an important factor for interpreting the craniometric differences between these populations.

The older populations (Bronze Age from Catalonia and from Andalusia) also form a single cluster. The former has been related to brachycephalic foreign elements coming from central Europe and related to the megalithic culture, the practice of the trepanning and the prospecting for metals (Turbón, 1981). However, this hypothetical foreign element does not represent a special difference with the contemporary and posterior peninsular substrate.

The Visigothic sample clusters with medieval Catalonia. In the first group, a possible Nordic component has been described (Schwidetzky, 1957; Varela, 1974–75), which could have contributed to its large stature and dolichocephaly. The size of the Visigothic contingent that entered the Iberian Peninsula in A.D. 415 is controversial, and numbers of about 80,000 (Guichard, 1987) or 80,000–100,000 individuals (García de Cortázar, 1974) over a total Hispano-Roman population of about 4 million (García de Cortázar, 1974) or more have been proposed. With certainty, the demographic impact of the Visigoths over the peninsular substrate (and therefore, the genetic impact) must have been of little importance (Vives, 1987), representing perhaps 2–4% of the whole peninsular population. A Nordic influence has also been suggested in the medieval people from Catalonia, related to the establishment of the Marca Hispanica in the Carolingian period and to the repopulation of the border lands with Franks (Turbón, 1986). The Visigoths and the medieval Catalans have a large maximum cranial length and large upper facial length, as reflected in the principal coordinates analysis. These traits can be correlated with the high stature that these series present [167.61 in average, in Visigoths (males) (Varela, 1974–75) and 165.80 in average, in medieval Catalans (males) (Vives, 1987)], and may be attributed to the contribution of elements from Northern Europe. It seems reasonable to expect some morphological affinities between some of these popu-

lations that contribute to clustering them together (e.g., oriental influences in Balearic samples and northern influences in Visigothic and medieval Catalan samples). Nevertheless, it is worth pointing out the little morphological variability that these samples contribute in comparison to the Basque uniqueness.

It is necessary to state that, by studying historical sites, more importance is granted to some groups that attracted the attention from an ethnic or archaeological point of view, like the Visigoths, the Muslims or the Jews, although each may be a minority when considering the total population of a region. Accordingly one must heed the possibility that the descendants of some of these groups may hardly have influenced the later population of the Iberian Peninsula. Despite these limitations in the sampling, the degree of correlation between the craniometric data and the genetic data in the Iberian peninsula is surprisingly high, showing the morphological and genetic differentiation of the Basque population.

From our point of view, the traditional racial types described from the skull morphology are all part of the general range of variation of the Mediterranean populations. Although the "western-pyrenaic" racial type can reflect the Basque morphological differentiation and the uniformity of the other peninsula populations can correspond to some extent to the ambiguous and predominant "gracile Mediterranean" type, it seems clear that craniometric variation in the Iberian Peninsula and Balearic Islands can no longer be explained in racial terms.

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